

Niskayuna Summer Invitational Single Elimination 4

TOSS-UP

1) Physics – *Short Answer* ANDrey is really tall, standing at a height of 9ft. However, being tall comes with its issues. Assuming that the human body can exert a maximal tension force of 1000N, if ANDrey were to stand on the surface of planet Meep, at his height, the tidal forces are just strong enough that he would be ripped in half! If planet Meep doubled its radius while maintaining constant density, what would be the minimum height, in feet, ANDrey would need to be for tidal forces to rip his body apart when he stands on Meep's surface?

ANSWER: 9

BONUS

1) Physics – *Short Answer* ANDrey is playing with charges on a coordinate plane. Currently, he has three point charges $+q$ on the xy -plane at the points $(0,0)$, $(1,0)$, and $(0,1)$. This system of charges has potential energy P . If andrey adds a fourth charge $+q$ outside of the xy -plane at the point $(0,0,1)$, then, in terms of P and as a reduced fraction with radicals in simplest form, what is the potential energy between the four charges?

Answer: $(9+3\sqrt{2})/7 P$

TOSS-UP

2) Chemistry – *Short Answer* How many normal vibrational modes does carbon dioxide have?

ANSWER: FOUR

BONUS

2) Chemistry – *Short Answer* Isaac lives in a fictional world where the Boltzmann distribution follows an inverse-square, rather than exponential, probability distribution. That is, probability is proportional to $1/(E/kT)^2$ rather than $e^{(-E/kT)}$, where k is Boltzmann's constant and T is temperature. In this world, Isaac seeks to understand his brain, which can be thermodynamically modeled as a single particle which can be in one of an infinite number of states with energies kT , $2kT$, $3kT$, and so on. What is the probability that Isaac's brain is in its second excited state?

ANSWER: $2/(3\pi^2)$

TOSS-UP

3) Energy – *Short Answer* Researchers at Korea University claim to have discovered a room-temperature, ambient-pressure superconductor called LK-99 which supposedly exhibits partial diamagnetism. To verify these results, multiple independent researchers have tried simulating LK-99 computationally using density functional theory, or DFT. These simulations employ what common approximation used in molecular dynamics, which assumes that the nuclei of atoms remain fixed in space over time?

ANSWER: BORN-OPPENHEIMER APPROXIMATION

BONUS

3) Energy – *Short Answer* Researchers attempting to replicate LK-99 are analyzing their attempted replication studies using x-ray diffraction. In x-ray diffraction, what is the term for the pattern of spots produced by parallel crystal planes?

ANSWER: LAUE PATTERN

TOSS-UP

4) Earth and Space – *Short Answer* By name or number, identify the following 3 statements which are true concerning hurricanes:

- 1) Hurricanes may increase the carbon emissions of oceanic regions it passes over
- 2) Hurricanes may decrease the carbon emissions of oceanic regions it passes over
- 3) Hurricane wind speeds fall during eye wall replacement, when the new eye wall weakens the older eye wall

ANSWER: 1, 2, 3 (ACCEPT: ALL)

BONUS

4) Earth and Space – *Multiple Choice* Given that a Neptunian year is around 165 earth years, at what distance, in astronomical units, would an asteroid have to orbit to correspond to a 2:1 mean motion resonance with Neptune?

- W) 27
- X) 30
- Y) 48
- Z) 67

ANSWER: W) 27

TOSS-UP

5) Math – *Multiple Choice* Given that the lengths of two perpendicular but not intersecting chords are 10 and 15. Which of the following is closest to the radius of the circle? (DJ)

- W) 8
- X) 9
- Y) 10
- Z) 11

ANSWER: X) 9

BONUS

5) Math – *Short Answer* How many paths of length 2 are there on a simple graph with 5 vertices with degrees of 2, 2, 3, 3, and 4?

ANSWER: 14

TOSS-UP

6) Chemistry – *Short Answer* Rank the following four acids in order of increasing K_a : 1) para-methoxybenzoic acid, 2) meta-methoxybenzoic acid, 3) para-nitrobenzoic acid, 4) meta-nitrobenzoic acid.

ANSWER: 1, 2, 4, 3

BONUS

6) Chemistry – *Short Answer* The Bartoli Indole Synthesis, which forms indoles from ortho-substituted nitroarenes, starts by addition of 1 equivalent of Grignard reagent to the nitroarene. The intermediate formed from this reaction subsequently eliminates to form an oxidized alkoxy magnesium salt and the original arene with what functionality in place of the nitro group?

ANSWER: NITROSO (ACCEPT: NO)

TOSS-UP

7) Physics – *Short Answer* A charged particle is moving in a circular path with a constant speed. If the radius is halved and the speed is doubled, by what factor does the power emitted by the particle change?

ANSWER: 64

BONUS

7) Physics – *Short Answer* Identify all of the following radial potential energy functions that can form closed elliptical orbits: 1) $U = -1/r$; 2) $U = r^2$; 3) $-1/r^2$

ANSWER: 1 and 2

TOSS-UP

8) Biology – *Short Answer* Halichoerus grypus, commonly known as the grey seal, belongs to the monophyletic clade pinnipedia. By name or number, which of the following 3 species that are also pinnipeds. 1. New Zealand fur seal, 2. Walrus, 3. Steller sea lion (MK)

ANSWER: All

BONUS

8) Biology – *Short Answer* Auxin, a class of hormone in plants, plays a major role in photoperiodism, which is the response of a plant to the change of the length of a day across different seasons. What specific type of auxin, an aromatic compound with a carboxymethyl group, is directly involved in photoperiodism?

ANSWER: INDOLE ACETIC ACID (ACCEPT: INDOLE-3-ACETIC ACID, IAA, 3-IAA)

TOSS-UP

9) Earth and Space – *Short Answer* By name or number, identify the following 4 styles of volcanic eruption that are likely to generate pyroclastic flows:

- 1) Pelean
- 2) Hawaiian
- 3) Strombolian
- 4) Vulcanian

ANSWER: 1 AND 4

BONUS

9) Earth and Space – *Short Answer* By name or number, order the following 4 seismic waves by arrival time at the antipode, assuming no change in the wave type as it propagates through the earth. If they are not detectable by modern seismographs, omit them from the ordering.

- 1) S waves
- 2) P waves
- 3) Rayleigh Waves
- 4) Love waves

ANSWER: 2, 4, 3

TOSS-UP

10) Math – *Short Answer* Identify all of the following 3 dihedral groups that have 2 generators:

- 1) D6
- 2) D8
- 3) D10

ANSWER: ALL

BONUS

10) Math – *Multiple Choice* A unit cube has cylinders of radius $1/2$ cut from the center of the 2 faces such that it goes all the way through the cube. What is the volume of the missing region?

- W) $\pi/2 - \frac{1}{6}$ (READ AS: pi over 2 minus one sixth)
X) $\pi/2 - \frac{1}{3}$ (READ AS: pi over 2 minus one third)
Y) $\pi/2 - \frac{1}{2}$ (READ AS: pi over 2 minus one half)
Z) $\pi/2 - \frac{2}{3}$ (READ AS: pi over 2 minus two thirds)

ANSWER: Z) $\pi/2 - \frac{2}{3}$

TOSS-UP

11) Physics – *Multiple Choice* Consider some arbitrary electric field distribution generated by a system of charges. If this system of charges is accelerated to a constant relativistic velocity, which of the following statements is most accurate about the components of the electric field perpendicular and parallel to the velocity? (CH)

- W) The parallel component gets larger and the perpendicular component gets smaller
- X) The parallel component gets smaller and the perpendicular component stays constant
- Y) The parallel component stays constant and the perpendicular component gets smaller
- Z) The parallel component stays constant and the perpendicular component gets larger

ANSWER: Z) The parallel component stays constant and the perpendicular component gets larger

BONUS

11) Physics – *Short Answer* A spaceship is in a circular orbit around a star at a distance of 1×10^5 meters and with an angular velocity of 2000 radians per second. Assuming that the star's peak intensity occurs at a frequency of 5×10^{10} Hertz, what is the frequency of the peak intensity of light observed on the spaceship in Hertz to one significant figure and in scientific notation?

ANSWER: 7×10^{10} HERTZ

TOSS-UP

12) Energy – *Multiple Choice* Niskayuna Newtons Research Center is studying COVID-19, and wants to purify a sample of the virus’ “spike protein” along with its associated proteins. Which of the following assays should the Niskayuna Newtons use?

- W) Immunoprecipitation
- X) Co-Immunoprecipitation
- Y) Enzyme linked immunoassay
- Z) Western Blot

ANSWER: X) CO-IMMUNOPRECIPIATION

BONUS

12) Energy – *Short Answer* In 2023, National Health Institutes researchers discovered that the drug metformin greatly reduces the severity and length of COVID-19 infections. What other disease is metformin commonly used to treat?

ANSWER: TYPE-2-DIABETES (ACCEPT: DIABETES, DIABETES MELLITUS)

TOSS-UP

13) Biology – *Short Answer* During inhalation, the blood pressure decreases slightly due to the negative intrathoracic pressure relative to the atmosphere caused by the expansion of the chest. What is the name of an exaggerated drop in blood pressure during inhalation that exceeds 10 mmHg? (DY)

ANSWER: PULSUS PARADOXUS

BONUS

13) Biology – *Multiple Choice* Statins are a class of medication that disrupt the synthesis of cholesterol by disrupting the mevalonate pathway. Which of the following statements is true about the mechanism of action of statins?

- W) It disrupts the formation of HMG-CoA by inhibiting HMG-CoA synthase.
- X) It inhibits the formation of mevalonate by inhibiting HMG-CoA reductase.
- Y) It inhibits the creation of acetoacetyl-CoA by inhibiting acetoacetyl-CoA thiolase.
- Z) It prevents the phosphorylation of mevalonate by inhibiting mevalonate-5 kinase.

ANSWER: X) IT INHIBITS THE FORMATION OF MEVALONATE BY INHIBITING HMG-COA REDUCTASE

TOSS-UP

14) Earth and Space – *Short Answer* By name or number, identify all of the following 3 classifications that describe Pallasites, which are meteorites with olivine crystals in a metallic matrix.

- 1) Achondritic
- 2) Stony Irons
- 3) Magmatic Irons

ANSWER: 1 AND 2

BONUS

14) Earth and Space – *Multiple Choice* Tides can be modeled as shallow water rotary waves with a node at the center. In a frictionless circular tub of water 100m deep, with the same tidal conditions as diurnal regions on earth, to two significant figures, what is the maximum radius of the tub such that only one amphidromic point would exist at its center?

- W) 230 km
- X) 450 km
- Y) 900 km
- Z) 1800 km

ANSWER: X) 450 KM

TOSS-UP

15) Math – *Short Answer* How many x intercepts does the graph of $y = \log(e^2 - x^2)$ (READ AS: y equals the logarithm of the quantity e squared minus x squared) have?

ANSWER: 2

BONUS

15) Math – *Short Answer* What is the nullity of a 2023 by 2022 reduced echelon matrix, given that it has 20 pivot columns?

ANSWER: 2002

TOSS-UP

16) Chemistry – *Multiple Choice* In infrared spectroscopy, two narrow bands around 3400 inverse centimeters is most characteristic of which of the following functionalities?

- W) Primary amine
- X) Secondary amine
- Y) Primary alcohol
- Z) Secondary alcohol

ANSWER: W) PRIMARY AMINE

BONUS

16) Chemistry – *Short Answer* Bob has a pure colorless organic liquid. When he runs it under proton NMR, he observes two peaks at 3.2 ppm and 1.2 ppm, with the peak at 1.2 ppm having an integration 3 times greater than 3.2 ppm. Given that the compound contains at least 1 oxygen, at least 2 carbon atoms but no double bonds, what is the identity of Bob's compound?

ANSWER: METHYL TERT-BUTYL ETHER

TOSS-UP

17) Energy – *Short Answer* Researchers at Oak Ridge National Lab have discovered a light-independent methylmercury degradation pathway in phytoplankton. What name is given to the group of highly reactive chemicals formed from diatomic oxygen that are the primary drivers of this pathway?

ANSWER: REACTIVE OXYGEN SPECIES (ACCEPT: ROS)

BONUS

17) Energy – *Multiple Choice* Which of the following statements is not true about reactive oxygen species?

- W) ROS formation can be stimulated by pollutants
- X) ROS are induced by the immune system as a response to infection
- Y) The superoxide anion is the precursor to most reactive oxygen species
- Z) ROS are formed through an abnormal pathway in anaerobic respiration

ANSWER: Z) ROS are formed through an abnormal pathway in cellular respiration

TOSS-UP

18) Biology – *Short Answer* What is the name of the process by which cells change directional growth to account for the presence of an electric field? (MK)

ANSWER: ELECTROTROPISM (ACCEPT: GALVANOTROPISM)

BONUS

18) Biology – *Short Answer* What is the name for the hereditary inheritance exhibited by the meiotic segregation of the mitochondrial genome which results in the same mitochondrial genes present in all daughter cells.

ANSWER: NON-MENDELIAN INHERITANCE (ACCEPT: CYTOPLASMIC INHERITANCE)

TOSS-UP

19) Earth and Space – *Short Answer* What term best describes the accreted material that makes up most of the western United States?

ANSWER: EXOTIC TERRANES

BONUS

19) Earth and Space – *Short Answer*

By name or number, identify the following 3 types of AGN where narrow line regions are visible.

- 1) Seyfert 1 Galaxy
- 2) Seyfert 2 Galaxy
- 3) Radio Loud Quasar

ANSWER: ALL

ESTIMATION

20) Estimation – *Short Answer* Arjun/Mihir has previously decided on a number between 1 and 200 that has meaning to him. What is it?

ANSWER: 179